Chapter 14

Property infrastructure

Key points

- Infrastructure is critical for property management. Roads and tracks provide access; fences, laneways, stockyards and holding paddocks are required to manage livestock; firebreaks protect important assets; and watering points and irrigation structures provide an essential resource.
- Infrastructure that is well planned and constructed will provide many years of satisfactory service and require limited maintenance and repair whilst infrastructure that has been poorly designed and constructed will require constant attention.
- Farm infrastructure can exacerbate existing erosion and/or initiate new erosion. When planning and installing new farm infrastructure it is worth investing time and effort to get it right the first time. Retrofitting erosion mitigation elements to existing infrastructure is usually less effective and more expensive than designing and constructing the infrastructure to mitigate, or prevent, erosion in the first place.
- The alignment of linear infrastructure—such as roads and tracks, fences, pipelines, channels or drains—in relation to the landscape is an important influence on erosion risk. As a general rule, linear features aligned along the contour, up and down the slope, or along ridges are least likely to cause erosion. Wherever possible linear features should not be aligned across the slope at an angle as this will increase the likelihood that they will intercept and concentrate runoff leading to erosion. If this is unavoidable, cross-drainage structures such as whoa-boys should be installed at appropriate intervals.
- When locating non-linear infrastructure, such as water points, storages, pumps and buildings, it is important to consider the soil type (especially if it is dispersive) and the position in the landscape (e.g. if it is on a floodplain).

Contents

Glossary

whoa-boy: trafficable banks constructed across a track to divert water off the track without causing erosion and to allow vehicles to cross over them. Also referred to as water bars, cross banks, humps or diversion banks.

culvert: one or more adjacent enclosed conduits for conveying runoff under a roadway or other structure.

erodibility: susceptibility (of a soil type, or part of the landscape) to erosion.

floodway: a long, low section in a road which allows flood waters to flow across it.

geofabric: permeable fabrics, typically made from synthetic materials, which when used in association with soil have the ability to separate, filter, reinforce, protect or drain.

gibber: angular fragments of broken up duricrust (hard layer on or near the surface of soil; usually silcrete) that form a rock- or pebble-littered surface on some broad plains of arid or semi-arid Australia.

invert: the lowest portion of the internal surface of a channel or pipe. Where trickle flows occur in earth channels, the invert may have to be lined with concrete or similar material to prevent erosion.

riparian: belonging to a river bank. Riparian vegetation is that which occurs from normal river level to the edge of the floodplain.

sodosol: a soil defined in the Australian Soil Classification system as having a clear or abrupt textural B horizon and in which the major part of the upper 0.2 m of the B2 horizon (or the major part of the entire B2 horizon if it is less than 0.2 m thick) is sodic (i.e. has an exchangeable sodic percentage of 6 or greater) and not strongly acid (i.e. has a pH of greater than 5.5). Soils of this type are characteristically highly dispersive and are prone to gully erosion.

spur drain: a drain to conduct runoff from a road shoulder to a disposal area away from the road alignment (also called mitre drain).

table drain: side drain of a road running adjacent and parallel to the shoulders and comprising part of the road formation.

tail water: excess surface water draining away from a field under irrigation.

14.1 Introduction

Infrastructure is critical for property management. Roads and tracks provide access; fences, laneways, stockyards and holding paddocks allow livestock to be moved and managed; firebreaks protect important assets (such as buildings); and watering points and irrigation structures provide an essential resource input. Pipelines and roads may be part of property infrastructure or part of larger-scale community or industrial networks. Well-sited and properly constructed property infrastructure can give many years of low-maintenance service. Poorly located and inappropriate improvements can create erosion problems and increase maintenance costs.

14.2 Roads and tracks

It is common for erosion on rural properties to be associated with roads and tracks. This erosion can reduce the usability of the road or track itself, affect access to other areas, increase the cost of maintaining the road or track, and/or reduce the quality of water downstream.

A road or track may show no obvious signs of erosion for many years until a big rainfall event occurs. Heavy rain is frequently blamed for causing serious damage to roads, but the root of the problem usually lies much earlier, with the way the road was built in the first place or the way it has, or has not, been maintained. Water runs off the compacted surfaces of roads and tracks at much higher rates than it does from the more pervious surrounding landscape. Roads and tracks also concentrate runoff from overland flow. Water always follows the easiest path and given a choice will flow down a bare road surface rather than through adjacent paddocks vegetated with pastures or crops. For this reason, it is very important to take the nature of the surrounding landscape into account when choosing a location and alignment for a road or track.

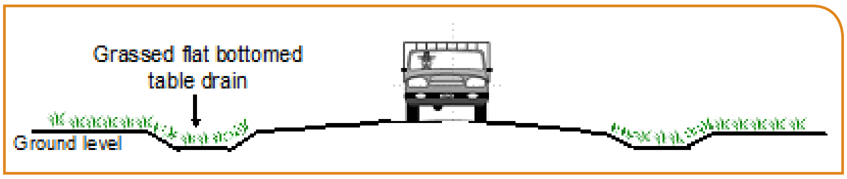
14.2.1 Road and track cross-sections

The shape (or cross-section) of roads or tracks has a big influence on how they perform and how much maintenance they require. Roads or tracks may take one of four possible shapes:

Formed or crowned roads (Figure 14.1) are expensive to construct and consequently are generally only used for the most frequently accessed parts of a property, such as the main driveway. When constructing or maintaining formed roads the following should be kept in mind to avoid erosion:

- Table drains should be grassed and flat bottomed (rather than v-shaped). It is tempting to reduce the width of a road reserve by using v-shaped drains but this should be avoided as it can lead to erosion.
- Runoff flowing down the table drains should be managed by installing spur drains at regular intervals to disperse runoff, and so avoid scouring table drains and forming gullies.
- Where it is necessary for runoff to cross the road it should be confined to culverts or whoa-boys that are low, trafficable earth banks designed to intercept runoff flowing down a road or over floodways or inverts.

Figure 14.1: A formed (or crowned) road



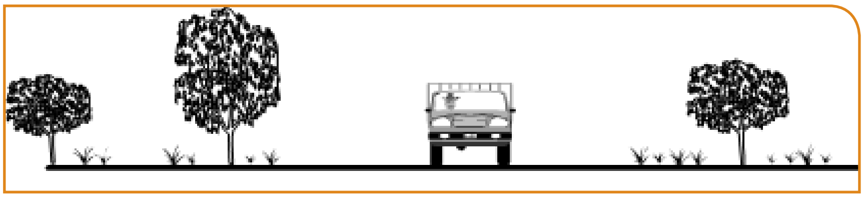
Ground-level tracks (Figure 14.2) are suitable for low-traffic situations such as in accessing more remote parts of the property. When constructing or maintaining ground-level tracks the following should be kept in mind to avoid erosion:

- When making a new track or maintaining an existing one, obstacles should be removed with a stick rake or very light grading. This will minimise disturbance of the soil surface and prevent windrows of soil being created alongside the road, which will divert and concentrate runoff. On the gibber plains of western Queensland, tracks can be created using a roller to ensure that the gibber mantle remains intact

- Where it is necessary for runoff to cross the road it should be confined to whoa-boys on sloping land, or inverts in drainage lines.

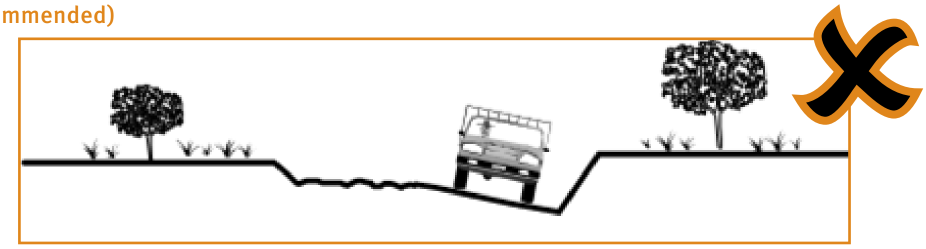
It is common for ground-level tracks to eventually develop wheel ruts due to wear and soil compression, particularly if the track is used when the area is wet. Where wheel ruts develop, they can divert and concentrate runoff and quickly develop into deep gullies. In some cases where wheel ruts have developed it may be possible to move the affected section of track sideways to a new alignment. This will allow the old alignment an opportunity to rehabilitate by revegetation with grass.

Figure 14.2: Roads or tracks at ground level



Subsurface roads (Figure 14.3) are a common consequence of poor road and track construction and maintenance. Formed or surface roads become subsurface when they wear following regular usage or when they are graded inappropriately. Subsurface roads should be avoided. They are at high risk of becoming an eroding waterway or gully. This is because they attract and concentrate overland flows and expose the subsoil that is often highly erodible.

Figure 14.3: Subsurface roads (not recommended)



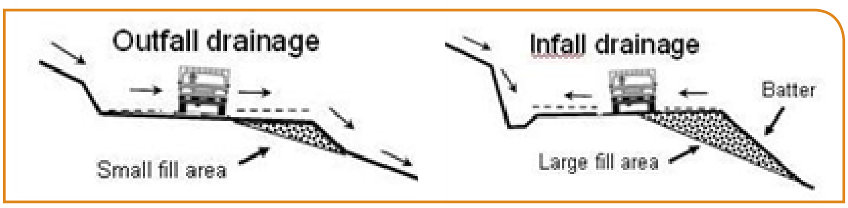
Outfall roads (Figure 14.4a) allow overland flows to disperse freely across the road in the same direction as the general slope of the land. They are a good option for low-usage areas on steep slopes. When constructing or maintaining outfall roads the following should be kept in mind to avoid erosion:

- Upslope and downslope batters need to be stabilised soon after construction.
- Roads should be built and maintained with a cross-fall of 15–25 cm to ensure that drainage is adequate.

Infall roads (Figure 14.4b) are similar to outfall roads except that they drain in the opposite direction to the general slope of the land. Infall roads are more onerous than outfall roads to construct and maintain, and the risks of erosion are greater due to the following requirements:

- Additional table drains and culverts are necessary to control internal and overland runoff.
- A larger fill area means that the amount of earth needed to be moved and the area of batter exposed is greater, increasing the risk of water erosion and slumping.

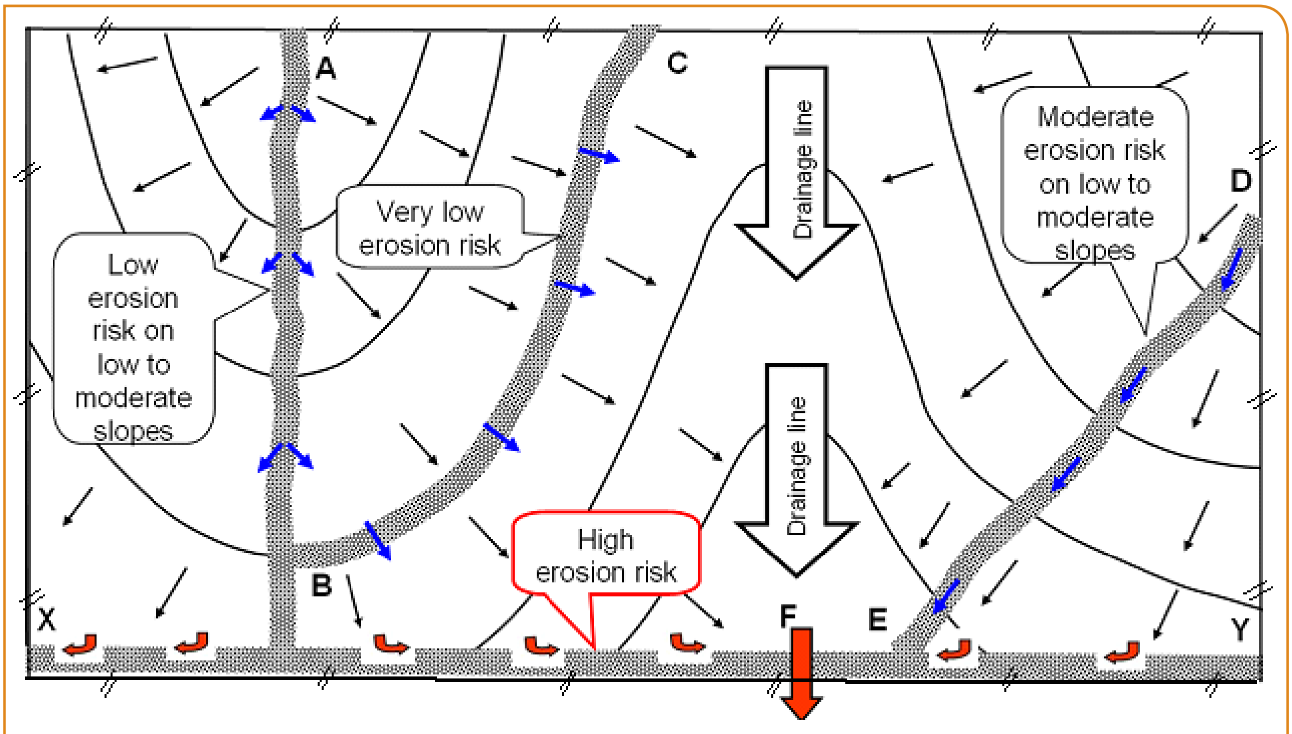
Figure 14.4: Cross-slope roads



14.2.2 Road and track location

The risk of erosion resulting from roads and tracks also depends on their location in the landscape. Figure 14.5 shows the different ways that roads and tracks may be located in relation to the topography. The arrows represent the direction of runoff in the landscape. Tracks and roads that take the shortest route often have the most erosion problems as they commonly cross slopes on a diagonal to maintain their straight alignment, and so divert and concentrate runoff. When choosing an alignment for a track it is important to bear in mind that if the alignment requires any clearing of native vegetation all requirements under the Vegetation Management Act 1999 must be followed before commencing the work.

Figure 14.5: Location of a road or track in relation to the landscape



Roads and tracks on ridges

Ridges (e.g. section A–B in Figure 14.5) are an excellent location for roads and tracks. Ridge slopes are not as steep as adjacent slopes and runoff naturally drains away from ridges. However, whoa boys will still be required where the ridge line slopes for extended distances, particularly on the toe, or if the road diverts along a spur. Roads on ridges are excellent vantage points from which to inspect a property because a large area of land can be seen from them.

Roads and tracks on the contour

Along the contour (e.g. B–C in Figure 14.5) is also a good alignment for roads and tracks. Whoa-boys are not required for roads and tracks that follow the contour, and maintenance costs are reduced because runoff is not accumulated. Surveying for contoured roads need not be highly accurate as minor deviations from the contour can allow wheel ruts formed in wet conditions to drain more quickly after rain. Roads and tracks on the contour have the added benefit of enabling access to, and inspection of, the middle of a paddock.

Roads and tracks directly up and down slope

A road running directly up and down the slope (such as D–E in Figure 14.5) usually has a lower risk of erosion than one running diagonally across the slope (such as X–Y in Figure 14.5). A road up and down the slope may be steeper and hence potentially more difficult to traverse, particularly when wet, but it will not intercept overland flow and hence has fewer drainage issues. Whoa-boys will usually be required on roads running directly up and down slope to manage runoff flowing down the road and to avoid scouring and gully formation.

Roads and tracks diagonal to the slope

Tracks along fence lines will often run diagonal to the slope (e.g. X–Y in Figure 14.5). Roads on such an alignment are at high risk of erosion because they divert and concentrate runoff from a large 'catchment'. A diagonal road will intercept overland flows and redirect runoff down the road or table drain. This can deprive the land on the low side of the road of useful runoff. To overcome erosion problems, whoa-boys or culverts must be installed at regular intervals, along with spur drains to safely disperse runoff.

14.2.3 Roads and watercourses

Where formed roads cross drainage lines or creeks (e.g. point F in Figure 14.5), an invert, floodway, causeway, culvert or bridge is required. Inverts are constructed by removing the soil in the crossing and replacing it with heavy gravel or concrete. A sheet of geofabric laid under the gravel will ensure that the gravel remains separated from the underlying soil. This is important to extend the effective life of the invert. If a culvert is being installed, the diameter of the pipes should be matched to the expected runoff (see Chapter 3 for estimating rate of runoff). The expected runoff will be related to the area drained by the culvert and the pattern of rainfall in the area. Culverts are susceptible to blockage from siltation as well as the growth of grass and weeds and it is important that they are maintained regularly.

Selecting the location at which a watercourse is to be crossed requires careful thought. The correct choice of a crossing location will reduce construction and maintenance costs as well as minimise any adverse impacts of the crossing on the watercourse. When siting a crossing the following should be considered:

- Avoid locating crossings where the banks are steep. Steep banks are an erosion risk and require considerable excavation to ensure that approaches to the crossing are gently sloping enough to be easily accessible.
- Whoa-boys should be installed on the approaches into the drainage line to avoid erosion of the road or track.
- Minimise disturbance of soil and vegetation by crossing drainage lines at right angles and avoiding sites where clearing of vegetation is required.

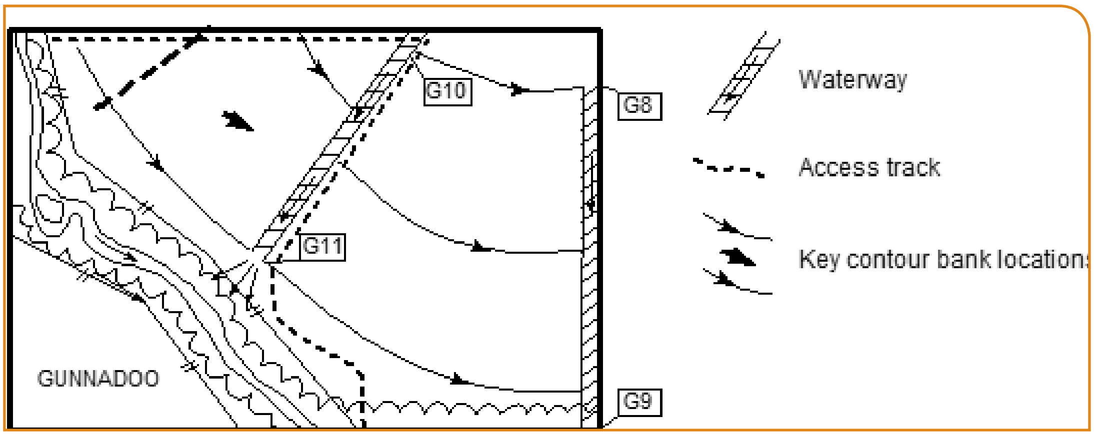
14.2.4 Roads and tracks in paddocks with contour banks

In paddocks with contour banks, the ideal place to locate a track is where contour banks are 'split' along a ridge line. This is the point where the banks diverge in opposite directions down either side away from the ridge. The likelihood that tracks may be located in this position should be taken into account when surveying the paddock to install contour banks in the first place. To make it easier for future track construction, care should be taken to ensure that the points where contour banks meet along broad ridge lines are aligned and that each split in the contour bank is marked with a stake or steel peg.

Tracks should never be located in the channel of a waterway used to collect runoff from contour banks. Even the occasional passage of vehicles along a waterway can create wheel ruts. Wheel ruts will concentrate runoff, leading to erosion and potentially causing the waterway to fail.

Locating tracks where they traverse the outlet end of a contour bank should be avoided. Tracks located in this way are likely to reduce the capacity of the contour bank. They will also be difficult to traverse in wet weather especially if sediment has been deposited in the channel. A much better way to locate tracks in relation to contour banks is to place them at or near the head of the banks. Examples of this are shown in Figure 14.6, on the eastern side of waterway G10–G11 or along the northern boundary of the property.

Figure 14.6: Track location in a contour banked paddock



Another option is to locate the access parallel to, but just below, a contour bank.

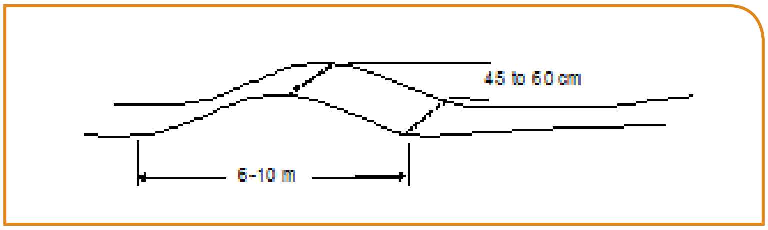
14.2.5 Managing runoff on roads and tracks

As discussed in the previous section, roads and tracks both produce runoff from their own surface as well as intercepting it from the land above them. Failure to manage this runoff will lead to erosion either of the surface of the road or track itself or of the land adjoining it. Whoa-boys and spur drains are two common methods for managing runoff on roads and tracks.

Whoa-boys

Whoa-boys extend across the road or track, diverting runoff to the edge of the road and allowing it to continue in its natural flow direction down the landscape (see Figure 14.7). Whoa-boys are also referred to as water bars, cross banks, humps or diversion banks.

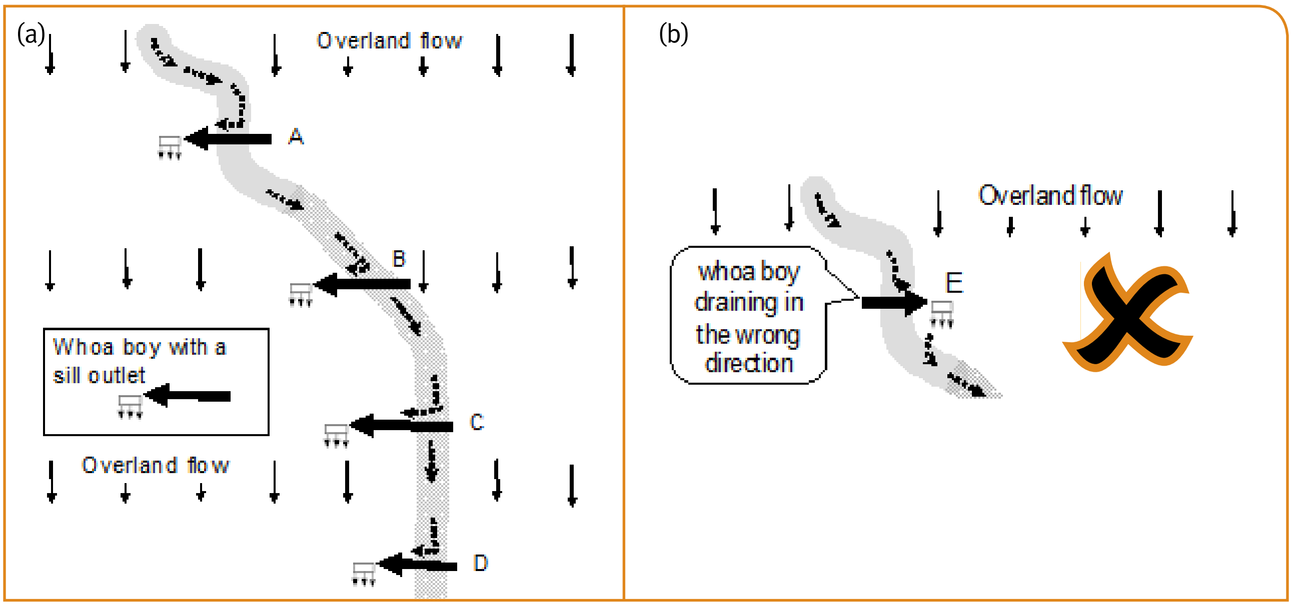
Figure 14.7: Cross-sectional view of a whoa boy



When choosing a location for a whoa-boy it is important to consider the direction of overland flow adjacent to the road. In flat landscapes it may be necessary to take some levels to be confident about which side of the road to divert the runoff. The whoa-boys at points A and B in Figure 14.8a are well located. Runoff from both of these is directed to areas that will not interfere with lower sections of the road. Point E on Figure 14.8b is an example of a poorly located whoa-boy. Runoff from this is flowing back towards the road and is likely to cause erosion. Where roads are situated on ridges or directly up and down the slope, runoff can be diverted to either side of the road (e.g. points C and D in Figure 14.8a).

To ensure that whoa-boys are most effective and easy to maintain it is preferable that they be constructed as close as possible to a right angle to the road direction. An example of this is Point A on Figure 14.8 a) where the road has been re-aligned so the whoa-boy crosses it at a right angle. However, if the road gradient is excessive or the alignment constrained it may be necessary to locate the whoa-boy on the diagonal to the road, such as for Point B on Figure 14.8a. This is because to locate it at right angles would require it to be built with an excessively steep face which would make it difficult to cross. However, siting a whoa-boy diagonally will make it less trafficable for vehicles or machinery.

Figure 14.8: Using whoa-boys to allow overland flows to cross a road (a) correctly and (b) incorrectly



There are no strict rules for working out how many whoa-boys are needed, or how close they should be together. However, the greater the number of whoa-boys, the easier it is to manage runoff. Some authors recommend that whoa-boys should be spaced further apart or closer depending on the climatic zone. That approach is not endorsed by these Guidelines. It is considered that the susceptibility of roads on dispersible soil types to erosion is just as great in the arid areas of south-west Queensland as in higher rainfall coastal areas. Table 14.1 provides general guidelines on whoa-boy spacing based on slope.

Other important considerations in locating and designing whoa-boys include:

- *soil erodibility*. Whoa-boys should be located closer together where subsoils are dispersible, as these soils are especially vulnerable to erosion.
- *land surface condition*. A whoa-boy should be located where the outlet can direct flows onto a stable grassed or stony area.
- *landform*. Whoa-boys will be most effective when located where there is a significant change in slope (see Figure 14.9a), or on the approach to a drainage line or creek (see Figure 14.9b).
- *other infrastructure*. Whoa-boys may be aligned with contour banks in cultivated areas or where they can discharge into farm dams.
- *existing erosion on the road*. When constructing whoa-boys in an existing road, the highest in a series should be placed just above any rills occurring in the road. If the erosion appears to be active, as an added precaution it may be necessary to start even further up the slope.

Table 14.1: Guidelines for whoa-boy spacing

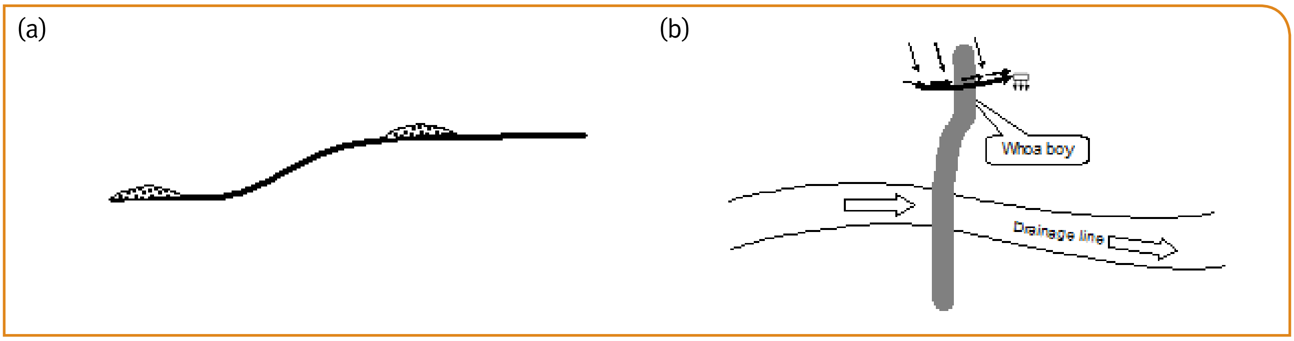
		Whoa-boy spacing	
Land slope (%)	Land slope (degrees)	Vertical interval (m)	Horizontal interval (m)
1	0.6	1.0	100
2	1.1	1.2	60
3	1.7	1.4	50
4	2.3	1.8	45
5	2.9	2.0	40
6	3.4	2.2	40
7	4.0	2.4	35
8	4.6	2.6	35
9	5.2	2.8	30
10	5.7	3.0	30

		Whoa-boy spacing	
Land slope (%)	Land slope (degrees)	Vertical interval (m)	Horizontal interval (m)
11	6.3	3.0	30
12	6.9	3.0	25
13	7.4	3.0	23
14	8.0	3.0	20
15	8.6	3.0	20
16	9.2	3.2	20
17	9.7	3.4	20
18	10.3	3.6	20
19	10.9	3.8	20
20	11.5	4.0	20

Other important considerations in locating and designing whoa-boys include:

- *soil erodibility*. Whoa-boys should be located closer together where subsoils are dispersible, as these soils are especially vulnerable to erosion.
- *land surface condition*. A whoa-boy should be located where the outlet can direct flows onto a stable grassed or stony area.
- *landform*. Whoa-boys will be most effective when located where there is a significant change in slope (see Figure 14.9a), or on the approach to a drainage line or creek (see Figure 14.9b).
- *other infrastructure*. Whoa-boys may be aligned with contour banks in cultivated areas or where they can discharge into farm dams.
- *existing erosion on the road*. When constructing whoa-boys in an existing road, the highest in a series should be placed just above any rills occurring in the road. If the erosion appears to be active, as an added precaution it may be necessary to start even further up the slope.

Figure 14.9: Locating whoa-boys a) at changes in slope; b) at the approach into a drainage line



Specifications for whoa-boys

The size and shape of whoa-boys, and the techniques used to construct them, depend on the slope in the road and the amount of runoff they need to accommodate.

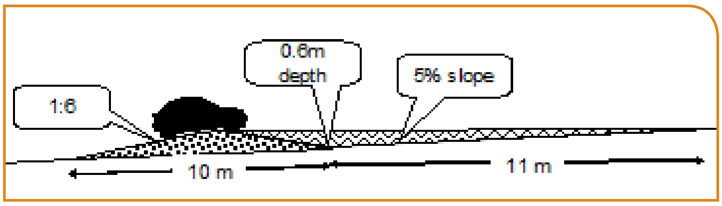
Whoa-boys may be required on slopes as low as 1%. A slope of 1% has a fall of 1 m in 100 m which can be sufficient to create an erosion problem. Table 14.2 shows the cross-sectional capacity for whoa-boys constructed to a height of 45 cm and 60 cm assuming that there is no cut-and-fill (refer to the later section on constructing whoa-boys). The capacity of the channel behind a whoa-boy decreases dramatically as the slope increases. Whoa-boys with a height of 45 cm may be acceptable on slopes of 1–2% and in other situations where there is minimal overland flow. A 60 cm height provides more safety on slopes above 2% and these whoa-boys will have a longer maintenance interval. Some settlement will occur depending on the method of construction.

Table 14.2: Cross-sectional area (m2) of the channel (assuming no cut-and-fill) for whoa-boys constructed to a height of 45 cm and 60 cm

Land slope (%)	Cross-sectional area	
	Whoa-boy 45 cm above channel	Whoa-boy 60 cm above channel
1	10.5	18.8
2	5.6	9.8
5	2.6	4.4
10	1.6	2.6

The broader the batter the easier it is to cross a whoa-boy. Whoa-boy batters should be somewhere between 1:4 and 1:8 (see Figure 14.10) depending on the type of vehicle using the track and the slope of the land.

Figure 14.10: A cross-section of a whoa-boy on a 5% slope, assuming no cut and fill



As the slope of the road increases, it becomes more difficult to provide sufficient cross-sectional capacity for drainage while keeping the whoa-boy batters at trafficable slope and height. Even high-clearance vehicles have difficulty negotiating whoa-boys on slopes steeper than 20%. Whoa-boys on steep slopes can be built either by using a cut-and-fill technique (Figure 14.11a) or by importing soil (Figure 14.11b). Figure 14.11a shows that to build a whoa-boy that provides a 60 cm channel depth on a 20% slope using cut-and-fill requires considerable earthmoving with up to 90 cm depth of soil needing to be excavated to form the up-slope batter leading into the channel. This batter would be very susceptible to erosion. The total distance required to build such a whoa-boy is around 20 m.

Table 14.3 compares the cross-sectional areas that will result when whoa-boys are built with cut-and-fill or with imported material.

Figure 14.11: A 60 cm high whoa-boy constructed on a 20% slope by a) using cut-and-fill, and b) importing road building material

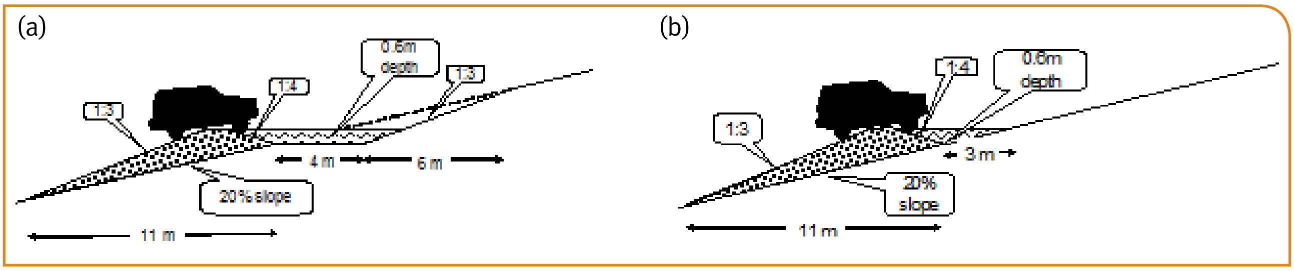


Table 14.3: Cross-sectional area (m^2) of the channel for whoa-boys built with and without cut and fill

Land slope %5)	Without cut and fill		With cut and fill	
	Whoa-boy 45 cm above channel	Whoa-boy 60 cm above channel	Whoa-boy 45 cm above channel	Whoa-boy 60 cm above channel
10	1.6	2.6	3.9	5.5
15	1.2	2.0	3.7	5.1
20	1.1	1.7	3.6	4.9

The height that a whoa-boy would be required to be built on a steep slope could be decreased to 45 cm if the road was constructed with an outfall type cross-section (see earlier Figure 14.4a). Roads of this design shed water along their entire length rather than allowing it to flow along the road building up volume and velocity and hence increasing erosion potential. Because of the cross-fall designed into such a road, additional cross-drainage structures such as whoa-boys would not technically be required at all. However, installing whoa-boys is not a major additional cost and it will provide useful insurance in case ruts develop and runoff starts to flow downslope along the road surface. A 45 cm high whoa-boy is comparatively easy to construct, presents a minimal barrier to vehicles, and would adequately deal with any runoff that flows down wheel ruts in the road.

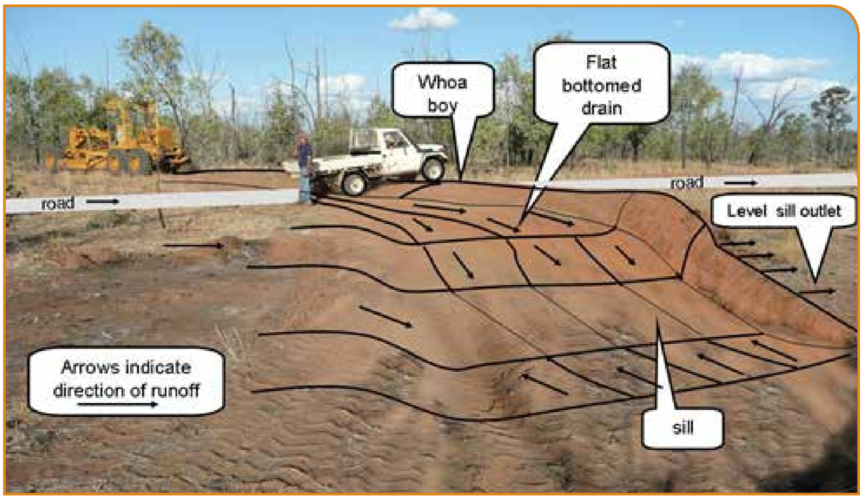
Whoa-boys should fall by 10–25 cm from one side of the road to the other. Runoff should flow into a grassed, flat-bottomed drain with a stable outlet such as a grassed or rock protected area. Flat-bottomed drains are preferable to V-shaped drains for receiving runoff from whoa-boys as they are much less susceptible to erosion. Flat drains are also easier to install and maintain and, as they can be shallower, there is less chance of exposing erodible subsoils than with V-shaped drains. Whoa-boy outlets can have gradients from 0.2% on lower slopes to 2% on steeper slopes. If the outlet is considered to be at risk of eroding, then gradients at the lower end of this range are recommended.

Constructing whoa-boys

Whoa-boys can be constructed using a grader, dozer or scraper. For road slopes of up to 10%, the material to construct the whoa-boy can be collected from the road surface either above or below the mound. For slopes above 10% the mound should be built from the top side using cut-and-fill or material imported to the site. Where subsoils are dispersible care should be taken to not expose them. One way of doing this is by importing soil or gravel to the site using a scraper. The soil on which the mound is constructed should be ripped beforehand to ensure that the soil in the mound binds well with the soil below it.

The sill constructed to receive runoff at the whoa-boy outlet can be a useful source of soil to build the mound for a whoa-boy (Figure 14.12). A sill is a level excavation at the end of any structure (e.g. a contour bank), to ensure runoff from that structure is spread to reduce its velocity and hence erosive power. Sills are usually about 10 m long, 6 to 9 m wide, and 20 to 30 cm deep. The sill outlet should be surveyed to ensure it is level.

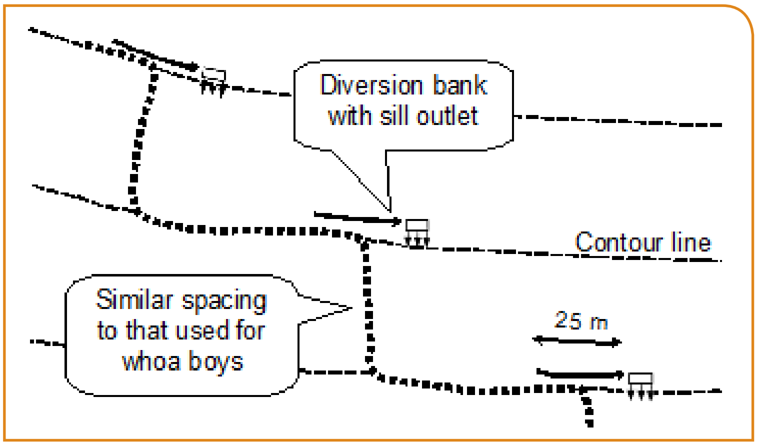
Figure 14.12: A whoa-boy with a sill outlet to spread runoff



Zigzags

By locating a track on a zigzag alignment (see Figure 14.13) it may be possible to avoid having to construct whoa-boys. This type of alignment can be particularly useful for graziers who need to travel through the middle of paddocks on a regular basis (e.g. to deliver animal feed supplements). Rather than being aligned in a relatively consistent diagonal across a slope, a zigzag track is aligned in sections that are either on the contour or run directly up and down the slope. The sections that are on the contour will naturally shed runoff whilst the up- and down-slope sections can be protected by short diversion banks.

Figure 14.13: Road traversing a slope by alternating sections on the contour and up and down slope

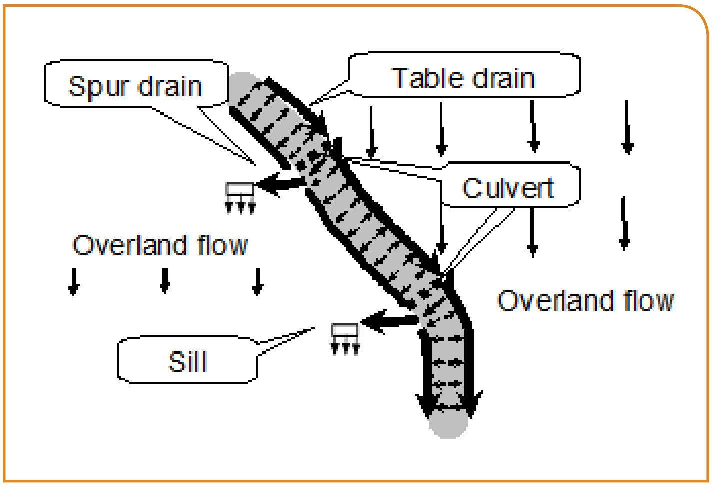


Putting zigzags in can make it easier to drain a road on steeper slopes. The zigzagging reduces the length of each section of track as well as its slope, and runoff can be drained from the road at each change in direction. A downside of this design is that having frequent corners such a road will be longer than it may otherwise be and more difficult to negotiate with long vehicles.

Spur drains

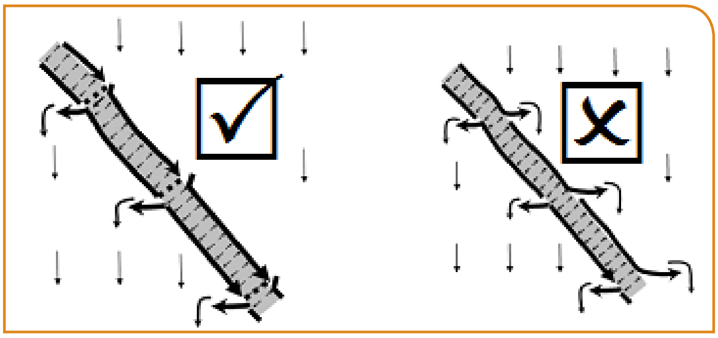
On formed roads whoa-boys will usually not be the most appropriate method to manage cross-drainage. It is much more common in these situations to move water from one side of the road to the other through culverts (i.e. pipes). Spur drains (Figure 14.14) are used in conjunction with culverts (and with table drains) to direct runoff from the outlet on to adjacent land where it can be safely spread. Spur drains are also referred to as turnouts, mitre drains, spoon drains or offshoots.

Figure 14.14: Spur drains collecting runoff from table drains and culverts on a formed road



As a general rule, spur drains should be spaced at similar intervals as specified for whoa-boys (see Table 14.1) under the equivalent conditions. In cultivated areas this spacing may need to be varied so that the spur drains connect up to contour banks if they are present. When a road is aligned across the slope, runoff directed by spur drains to the uphill side will, within a short distance, flow back to the road (Figure 14.15). This is to be avoided as it will cause the table drain to erode because the amount of runoff it has to accommodate will increase progressively down the slope and eventually exceed its capacity.

Figure 14.15: Correct and incorrect use of spur drains to remove runoff from a formed road



Spur drains should be constructed with channels that have flat bottoms rather than V-shaped. Table drains should also be constructed in this shape. A few additional metres of land will be required to construct a flat-bottomed channel but this is a small price to pay for the reduced risk of erosion. A sill constructed at the outlet of the spur drain (see illustration in Figure 14.12) can be a source of soil to construct and maintain the drain. Spur drains should be constructed with gradients similar to those for whoa-boys under equivalent conditions. The gradients for spur drains with flat-bottomed, grass-lined channels should range between 0.2% where the landscape is comparatively flat to 2% where it slopes steeply. If the channel is considered to be at risk of eroding, the conservative 0.2% gradient should be used under all conditions.

14.2.6 Maintaining roads and tracks

Table drains should be graded only if absolutely necessary. Grading table drains removes grass, exposes soil, potentially including dispersible subsoil, and causes erosion. Repeated grading of a drain can also lower the base of the drain to the point where it will no longer discharge. Runoff will then bypass the spur drain and continue down the table drain causing additional erosion.

Traditionally, spur drains are maintained by grading from the table drain outward toward the spur drain outlet. This continually moves soil downhill. Instead it is better to maintain spur drains in the opposite direction, grading from the outlet towards the table drain. If there is a sill at the outlet it will have collected sediment which can be spread to maintain the bank and ensure that the spur drain connects up with the table drain.

Figure 14.16: Subsurface road from which runoff cannot escape

When roads are graded to remove wheel ruts, soil from the road is often left as windrows which progressively accumulate along each side of the road. This eventually results in the road surface becoming lower than the surrounding land (Figure 14.16). A road in this condition becomes an eroding waterway from which runoff cannot escape. Instead, material graded off into windrows on either side of the road should be brought back onto the road during maintenance. Where windrows are unavoidable they should be located on the downhill side of a track and gaps should be created every 20–30 m to allow runoff to disperse in small amounts.

14.3 Fencing

Well-designed and constructed fences are essential infrastructure on any property. Without quality fencing, managing livestock and maintaining pastures can be a real headache. Straying stock are not only a danger to themselves and passing motorists but are also a sure-fire way to get neighbours offside. Fences are necessary to separate groups of stock or to rest/renovate pastures. However, fences are susceptible to damage by soil erosion and they may be contributing factors.

Fences, because they act as a barrier, tend to concentrate the movement of stock along and immediately adjacent to the fence line. As stock move up and down along a fence line they can create heavily worn tracks that will easily erode. The common practice of clearing firebreaks along fence lines can exacerbate this erosion, as can gates that concentrate traffic causing the soil around them to become bare and compacted and a source of runoff.

For practicality and economy, fences are usually built in as straight a line as possible. In undulating country it is inevitable that sections of a long straight fence line will run across the slope. This increases the likelihood that runoff will be diverted and concentrated along the fence line to form rills and gullies. In time, this erosion can damage fences, cause firebreaks and access tracks to become unusable, and degrade water quality.

14.3.1 Planning fencing layouts

Fences are expensive to build and to relocate so they need to be planned well in the first place. When locating fence lines as part of a property plan account should be taken of natural features and existing infrastructure. Fences can be susceptible to damage by erosion and flooding and they can concentrate runoff leading to the formation of gullies. This is accentuated if one side of the fence is more heavily grazed than the other. The situation can be compounded by the roads, firebreaks and stock pads that frequently follow fence lines as well as accumulation of silt and the presence of grass and weeds under and against the fence.

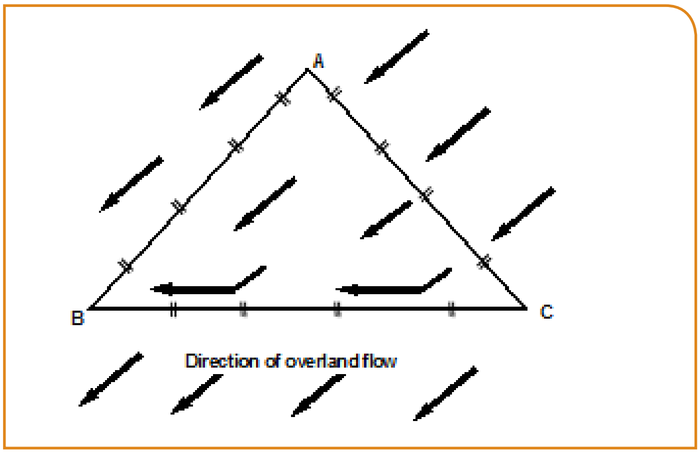
The layout of paddocks is a key consideration during the property planning process. Fences often follow a geometric pattern which ignores the local landscape. It can be useful to start by ignoring all existing fencing and developing an alternative layout which would be the optimal under current conditions. This optimal layout can then be compared with the existing layout to see where improvements can be made.

When planning fences a wide range of factors need to be considered:

1. Natural features
    - land types
    - watercourses and riparian areas
    - major ridges
    - areas requiring special attention, e.g. stony, wet or eroded areas
    - remnant vegetation, including the provision of a sufficient amount of shade and shelter for stock in each paddock. (Before carrying out any clearing for a fence line, requirements under the *Vegetation Management Act 1999* must be followed).
2. Existing infrastructure
    - buildings
    - yards and laneways
    - existing fencing
    - watering systems, dams, bores, tanks, troughs, pipes and waterholes.

Figure 14.17 shows three different ways in which fences might be aligned to the natural contours of the land. Section A–C is on the contour, and runoff would flow safely across the fence line provided there were no obstructions to flow such as wire-netting fences. However, on a floodplain a fence in this location would collect debris in a flood. The resulting pressure on the fence could lead to damage. Section A–B is directly up and down the slope, with runoff parallel to the fence. If the slope was steep, any roads or cattle pads along the fence would require whoa-boys or diversion banks to divert runoff from the fence line. Ridge lines run directly up and down slope and are ideal locations for both fences and tracks. Section B–C has the greatest potential to intercept and concentrate overland flows. The erosion risk becomes greater if there are roads or cattle pads. Wire-netting fences accumulate debris and soil and are especially at risk of diverting runoff.

Figure 14.17: Variations in how fences may be orientated to direction of overland flow



Where fences divert overland flows, it may be necessary to implement measures that allow runoff to pass under them at regular intervals. If the fence is on a property boundary, the matter should be discussed with neighbours. Landholders have common-law obligations in relation to runoff from neighbouring properties that they would receive under natural flow conditions.

14.3.2 Fence types

Fences can be constructed using a range of different materials and a variety of different designs. The most appropriate fence type to use will depend on factors such as the type of stock, the location of the fence, the nature of the landscape, and the budget. Table 14.4 summarises the advantages and disadvantages of common fence types.

Table 14.4: A comparison of fence types (Staton and O'Sullivan 2006)

Fence type	Advantages	Disadvantages
Conventional /suspension	• cheaper than mesh fences • can be cut if a flood is imminent to reduce damage • relatively easy to repair • relatively effective against cattle • additional wires can improve effectiveness against sheep and lambs	• difficult to follow curves • less effective against sheep than mesh fences
Prefabricated (mesh)	• very effective in controlling cattle, sheep and feral animals • very effective for managing lambs	• expensive • susceptible to flood damage • difficult to follow curves • likely to trap flood debris, leading to fence damage, water diversion and scouring
Electric fencing	• comparatively cheap • quick to erect and to carry out repairs • effective against a range of stock and feral animals • a curved fence line is possible • can be used easily to fence off stock crossings and waterways • easy to move (good option for temporary fencing)	• not as effective against sheep (but additional wires and closer spacing can improve effectiveness)

14.3.3 Fencing riparian areas

Frontage country (or riparian areas) associated with drainage lines, creeks and rivers needs to be managed with particular care. Riparian areas often contain the most fertile soils and hold soil moisture for longer than other parts of the property. Because of this, pastures in these areas are often 'sweeter' than elsewhere within the property and consequently are preferentially grazed by stock. Drainage lines, creeks and rivers are important natural water supplies and riparian areas therefore also tend to be more heavily trafficked than other parts of the property by stock seeking water. This heavier grazing pressure and increased traffic can subject riparian areas to severe erosion, with resulting water pollution and stream sedimentation. These issues can be managed by fencing off riparian areas and by providing off-stream water points.

Fencing riparian zones and providing off-stream water points can:

- prevent the streambed from being disturbed and becoming boggy
- prevent cattle pads forming and causing gullies
- assist gully rehabilitation
- create a fodder reserve that can occasionally be grazed strategically
- improve quality of water for stock and domestic consumption and for environmental reasons
- reduce weed spread
- assist mustering.

Stock need not be excluded completely from riparian areas. Fencing of riparian areas should be laid out to create paddocks large enough for them to function as stock management units. A useful 'rule of thumb' is that the fence should be offset onto the floodplain from the bank crest a minimum of 5 m plus a distance equal to the height of the bank, measured vertically from the toe to the crest of the bank. The width specified under this general guide is the minimum required to ensure stability of the stream bank. A fenced strip at least as wide as that calculated using this rule should be sufficient to ensure long-term viability and sustainability of the riparian zone vegetation and the local biodiversity (Boulter et al. 2000).

Where possible, fences should be located out of flood zones, especially those areas where there is likely to be fast-moving water. This generally means locating the fence on the high bank or on the high edge of the floodplain. Where fencing in flood-prone areas cannot be avoided, electric fences, 'drop-down' fences or suspension fences should be considered (see Chapter 10 Land management on floodplains). Drop-down fences are designed to automatically lie down as pressure from water and debris builds up behind them. They can also be designed to operate manually, especially in areas where considerable warning can be expected before a flood arrives. The simple 'cocky's gate' is an example of a lay-down fence. Floodgates are another option that can be used for fencing areas most prone to flooding.

Where fences cross broad drainage lines or floodplains they should be aligned at right angles to the direction of flow. This will reduce the potential for the fence to divert and concentrate floodwater, causing erosion, and will reduce the amount of debris the fence collects during a flood. Other general principles and tips about designing fences on floodplains include:

- Isolate fences 'at risk' of damage in a flood from other fences by using separate strainer assemblies.
- Thicker posts provide greater protection than thinner types.
- Deeper posts are stronger and less likely to be dislodged by a flood than shallow ones.
- Keep fence heights to a minimum.
- Fences constructed with barbed wire or mesh will collect more debris in a flood, and hence will be more prone to damage, than will those constructed with plain wire.
- Keep the number of droppers and wires to a minimum to reduce the amount of debris collected in a flood.
- Maintaining wire tension promotes vibration which can help to minimise debris load.

14.3.4 Fencing down streambanks

Fences aligned down streambanks at crossings are at particular risk of causing erosion (Shellberg and Brooks 2013). Precautions that should be taken in such situations include:

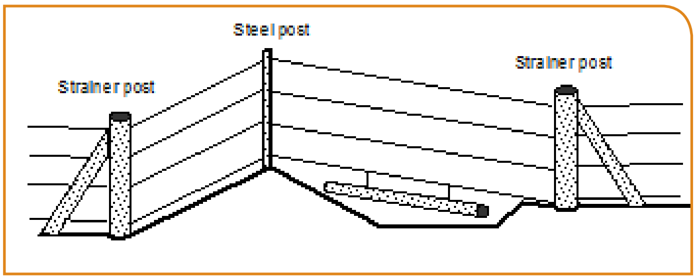
- Use existing live trees as fence posts (tree to tree) to avoid the need for clearing and soil disturbance.
- Bring past windrows from deep grading back onto the fence-line surface to avoid concentrating water, and use material to patch erosion areas and/or construct water division banks.
- Do not repeatedly grade fence lines as firebreaks or to provide access as this will accelerate erosion.
- If the fence line must be used as a firebreak, use slashing and herbicides rather than grading, taking particular care to maintain good grass cover on areas sensitive to erosion.
- Construct large water diversion banks (whoa-boys) at frequent intervals (every 10–50 m depending on slope) on top of the existing soil surface and make division banks particularly high (>0.5 m) and wide (6–10 m) to ensure long-term functionality and prevent future machine operators from grading through them.

14.3.5 Controlling fence-line erosion

It is much easier to prevent erosion by putting measures in place before a fence is built than to try and fix an erosion problem once the fence is in place. It is common practice when constructing a new fence to first clear and level the fence line with a bulldozer. Bulldozing removes major obstacles, making it easier to align the fence, and levels the land surface making it easier to ensure that the fence is stock-proof. However, bulldozing can increase the risk of fence-line erosion. This is particularly the case if the bulldozing has caused the fence line to be below ground level or if it has left windrows parallel to the fence line along which runoff can be channelled.

If the fence line is at an angle to the slope of the land (see B–C in Figure 14.17), whoa-boys may need to be constructed along the fence line to divert runoff and prevent erosion. Where a whoa-boy is crossed by a fence it is comparatively simple to create an opening in the fence when access is required to maintain the whoa boy (see Figure 14.18). Grass under fences will restrict water flows and may increase the risk of erosion. If grass growth is likely to become a problem, the section of the whoa-boy built under the fence should be constructed with additional fall of 150 mm over 30 m for slopes less than 5% (or 300 mm for slopes greater than 5%).

Figure 14.18: Fences built over banks or whoa-boys need to allow for opening up for maintenance



Sometimes holes in netting fences are ‘repaired’ by pushing soil up to the fence on either side. This practice should generally be avoided. It creates a bank that concentrates runoff and can cause erosion. It is especially a concern where the soils are of a type known as sodosols. These soils are dispersive and highly prone to erosion. They also often have a high salt content that may cause the fence to rust.

14.3.6 Fencing in areas with contour banks

Fencing in areas with contour banks presents many challenges. Permanent fences should not be constructed along the top of contour banks because their curved shape is an unsuitable alignment for a fence line and because the fence would interfere with maintenance of the contour bank. Similarly, fences should not be built in the channel of constructed waterways as any cattle pads or tracks along the fence line will be at high risk of erosion and a fence in this location will also interfere with maintenance of the waterway. Fences should also not be located across the outlet ends of contour banks as fences in these areas can interfere with channel flows as well as with bank maintenance.

The most suitable locations for fences in contour-banked paddocks are:

- along a split in contour-bank direction. Splits normally occur along a ridge line where contour banks divert to either side at different angles
- along the upper end of contour banks
- alongside waterways. However fences should never be located in a waterway

- at a practical distance above diversion banks. A distance of 10–15 m should be allowed to ensure that access to maintain the diversion bank is not restricted
- below contour banks. Electric fences are best for this location as it is easier to curve them to match the alignment of the contour bank.

Permanent fences should be located on the lower side of contour banks with a bit of flexibility to allow them to be built in a series of straight lines. A clear margin of about 3 m should be maintained between the toe of the downslope batter and the fence. This is to ensure that stock cannot become trapped between the bank and the fence, and that stock cannot use the bank to jump over the fence. Temporary electric fences may be more suitable than permanent fences in this location. Where it is not possible to avoid locating a fence at a contour bank outlet, it is useful to provide a gate where the fence crosses the channel to facilitate maintenance. Chapter 2 Soil conservation planning provides more information on fencing with contour banks.

14.3.7 Gateways

Gateways are the most heavily trafficked parts of a paddock. Livestock and machinery passing through gateways to move from one paddock to the next cause the soil around the gateway to become bare and compacted. Stock often congregate or camp near gateways, especially if they are used to being fed from a vehicle. Gateways and their approaches can be either a source of runoff contributing to erosion elsewhere, such as along the fence line, or can intercept runoff from other areas and suffer from erosion themselves.

To minimise erosion problems associated with gateways the following precautions are recommended:

- Locate them on stable soils not susceptible to erosion.
- If they become eroded or boggy, gravel gateways to improve access.
- Design the gateway width to accommodate machinery requirements as well as stock.
- Avoid locating gateways in depressions, in sites prone to seasonal waterlogging or in areas into which water is likely to drain (e.g. stock pads that can direct runoff to gateways).

14.4 Stockyards, holding paddocks, and laneways

14.4.1 Stockyards and holding paddocks

Locating and designing yards and holding paddocks is also an exercise in balancing the management needs of a property with the risk of erosion. Yards and holding paddocks are heavily used parts of the property and, like gates and laneways, tend to become bare and compacted leading to erosion problems. The following points should be considered when planning and constructing stockyards and small holding paddocks:

- Locate stockyards centrally. Access to the major holding yard can be provided either by a laneway or through connecting paddocks.
- Ready access to a secure water supply will be required.
- All-weather access for stock transport will be required.
- Ensure there is security against theft of stock.
- Locate yards on soils that drain well. Avoid heavy clays—loams or sandy loams are best.
- Land should be relatively flat but a little slope is ideal for surface drainage.
- Orient stockyards so that prevailing winds will blow dust away from other facilities.
- Consider including some trees or other shelter for wind breaks and shade.

14.4.2 Laneways

Laneways are used to move stock around a property. They also provide useful access for farm vehicles and machinery. Laneways need to be carefully located and constructed to ensure that they meet the management needs of the property and to avoid creating erosion problems. The management needs of a property will differ depending on the nature of the enterprise. The laneways needed by an intensively farmed dairy property near the coast will be very different from those needed to run an extensive grazing property in inland areas.

The drainage requirements of laneways are very similar to those of roads and tracks. Accordingly the same criteria as those for access roads and tracks discussed earlier in this chapter should be used for laneways. Narrow laneways that are frequently used and may become heavily pugged are likely to become bare and susceptible to erosion. If laneways start to recede below the land surface, as shown for roads in Figure 14.16, the risk of erosion will increase greatly. This is a particular risk for narrow laneways on dairy farms. To reduce that risk such laneways can be formed, compacted and gravelled. Forming and gravelling laneways will improve their trafficability, reduce their maintenance and repair costs, and reduce the amount of sediment they contribute into streams.

On large grazing properties, widening laneways (to as much as 300 metres wide) has the added advantage of allowing them to function as a temporary holding paddock. When used as holding paddocks wide laneways can provide valuable feed. Where wide laneways are used as a holding paddock it is desirable that shade be provided. However trees should be kept to just one side to avoid difficulties when handling stock.

14.5 Firebreaks

Firebreaks, also referred to as fire lines, are areas cleared of vegetation (sometimes including mineral earth barriers), created to assist in controlling fires. They function as a direct barrier to a fire spreading; they may also serve as a safe access from which to attack a fire directly, or as a line from which back-burning can be conducted. For firebreaks to be effective they need to be free of fuel, that is, clear of vegetation, sufficiently wide to not be easily crossed by a fire, and strategically located where they can be most effective. This can make them prone to erosion. It also means that before carrying out any clearing for a firebreak, any requirements under the Vegetation Management Act 1999 must be followed.

Firebreaks are often combined with other infrastructure such as existing tracks, roads and fences. Firebreaks on boundary fences should be planned in discussion with neighbours. A joint firebreak on both sides of the fence allows access for fence maintenance and may protect the fence from fire damage. Many firebreaks are constructed and maintained permanently; others may be constructed temporarily to contain an approaching wildfire. When this occurs there is little time to be concerned about erosion control. It is important that erosion control measures are implemented to rehabilitate such temporary firebreaks soon after the fire threat has passed.

14.5.1 Erosion control on firebreaks

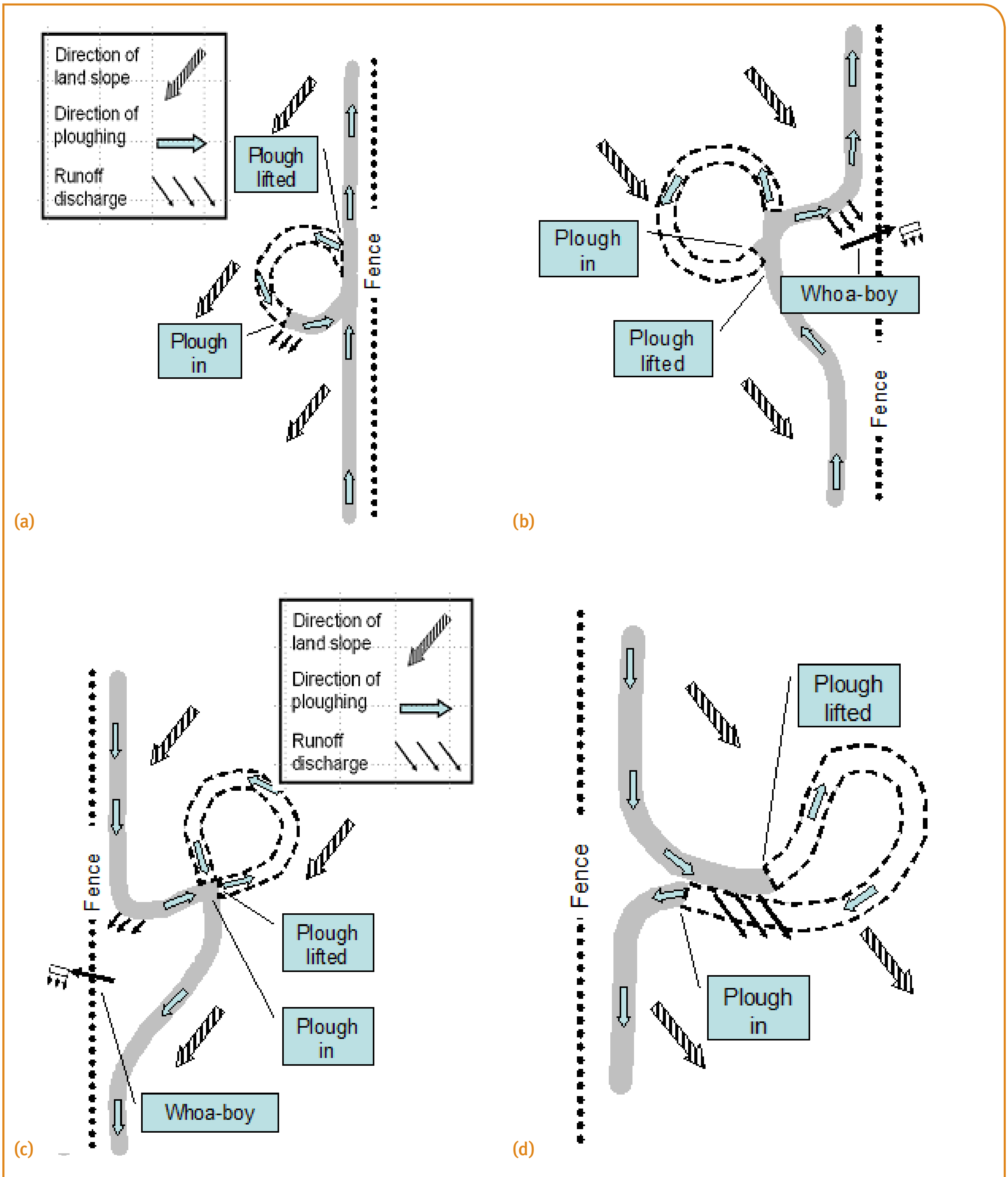
Firebreaks are usually built with machinery such as graders, bulldozers, disc harrows or fire ploughs. When building a firebreak the aim should be to create a flat profile, disturbing the soil as little as possible. If the firebreak is aligned as shown as A–B or B–C in Figure 14.17, whoa-boys should be constructed across it at regular intervals to divert and spread runoff and prevent the firebreak from channelling and eventually forming into a gully.

Frequent grading can create long piles, or windrows, where soil and debris is left at the edge of the angled grader blade. Windrows beside a firebreak, as shown in Figure 14.19, or channels running along it, should be avoided. If a windrow has formed, it may be removed by ploughing or grading in the opposite direction when the break is next maintained. When building firebreaks to control an approaching fire, any windrows should be directed to the side of the firebreak that is away from the fire. This is because logs in the windrow can continue to smoulder for several days. A strong gust of wind could spread sparks from these smouldering logs across the windrow and cause the fire to reignite.

Figure 14.19: Windrows created during firebreak construction

Firebreaks constructed by ploughing can be at a particularly high risk of eroding. This is because ploughing creates flow paths running longitudinally along the firebreak. These will intercept and concentrate runoff leading to erosion. Figure 14.20 shows examples of how runoff may be spread from a ploughed firebreak. The method varies depending on the direction of travel and the direction of the land slope.

Figure 14.20: Methods of dispersing runoff from furrows and windrows when a) and b) ploughing uphill, and c) and d) ploughing downhill



14.5.2 Constructing firebreaks without soil disturbance

Features of the landscape and vegetation that cannot support fire, or will inhibit the passage of a fire can be used as a 'natural' firebreak. Such features include water bodies such as rivers, lakes or dams, moist vegetation types such as rainforests, and rocky outcrops including cliff faces. Firebreaks can also be constructed using herbicide. This is best done with a non-residual herbicide such as glyphosate used during the season of most active plant growth.

The vegetation treated with the herbicide can then be burnt off as soon as it has died and before adjacent areas have cured sufficiently to carry a fire. Herbicide can be used in conjunction with other methods of firebreak construction. Once a firebreak has been constructed by a grader and diversion banks and/or whoa-boys constructed to protect it, a herbicide may be used in a regular treatment to avoid the need for annual grading. Slashing is another alternative for constructing firebreaks to avoid erosion risks. Vegetation that has been slashed low to the ground can slow the speed of a fire's spread and provide a stable surface for firefighting resources to get access to a fire. However, on a hot, windy day a slashed firebreak alone will not contain a fast running grassfire.

14.6 Watering points

Livestock need large amounts of water—beef cattle require upwards of 30 litres of water each per day, dairy cattle 70 litres, and sheep about 7 litres (New South Wales Department of Primary Industries 2014). Their need for ready access to a reliable source of water has a big influence on how stock graze different parts of a property. Generally cattle will restrict their grazing to an area within about 5 km from water points and sheep about 3 km (New South Wales Department of Primary Industries 2014). Giving careful thought to the location of watering points can help address, or avoid, a range of farm management issues including erosion.

The following points should be considered when locating watering points:

- Locate watering points as near as possible to the centre of a paddock to spread grazing pressure. Large paddocks may require more than one watering point. If a paddock has just one watering point located in a corner, this is likely to concentrate grazing pressure in the area around the water point, and cattle pads may funnel runoff if the watering point is lower in the landscape.
- Ridges are good locations for water points. This is because stock can approach from several directions, reducing the erosion risk.
- Locate water points on stony or firm ground in areas that are well drained.
- Avoid areas prone to degradation, such as highly erodible soils, or areas that become waterlogged such as drainage lines.
- Avoid areas where traffic is already heavy such as locations near gateways that are frequently used for access.
- Site water points in areas that are reasonably level and do not receive concentrated runoff.
- Place troughs on a concrete base and extend the base out 1–2 m to reduce erosion in the immediate vicinity of the trough.
- Shade immediately adjacent to a watering point may seem desirable, but it can further concentrate grazing pressure in the vicinity of the water point and worsen degradation such as soil erosion.
- Windbreaks can reduce wind and impair the performance of a windmill. However, they can also improve windmill performance if used to channel and direct wind correctly.
- Piping water away from dams and fencing them can improve water quality and encourage vegetation to regenerate around them, providing habitat for wildlife.
- The density and distribution of water points should be managed in areas with high conservation value, to control and direct grazing in order to reduce stock impacts on those areas.
- Where accessing artesian water, such as in the Great Artesian Basin, bores should be capped and piped to suitable locations rather than allowing them to discharge into open drains.

14.7 Irrigation infrastructure

The risk of erosion can be increased by irrigation. A degree of groundcover removal and soil disturbance is commonly required when constructing, maintaining and operating irrigation infrastructure. Irrigation infrastructure, such as storages, banks and channels, pumps and pipelines, divert and concentrate natural runoff, whilst irrigation practices can increase the amount of runoff and increase its erosive power. Irrigation systems are normally designed with the assistance of a professional with specialist knowledge about water supply technologies. However, such specialists are not always the best people to advise on erosion prevention or management.

14.7.1 Additional considerations

Many of the measures required to manage the risks of irrigation-related erosion are covered in earlier chapters of these Guidelines (see Chapters 6 to 8 for information on designing channels and banks and Chapters 9 and 10 for information on protecting waterways and floodplains). The following are some additional matters that may require particular consideration.

Drainage: is a key component of designing an irrigation layout. Drainage systems remove excess water whether it be applied naturally by rainfall (e.g. during storms) or artificially through irrigation. Drainage works for irrigation systems need to have sufficient capacity to minimise the risk of poor-quality water leaving the farm and should be designed to a standard that will ensure the energy of runoff is sufficiently reduced that it does not cause erosion.

Tail water: is residual irrigation water. Because tail water has passed through the crop, there is an increased risk that it contains concentrations of chemicals and nutrients that could cause degradation if not regulated in their return to the environment. Irrigation and drainage should be designed and managed to minimise generation of tail water. It is good practice to ensure that no tail water leaves the property without first undergoing appropriate treatment.

Pumps: are often installed in riparian areas and on waterway banks prone to erosion. Pumps should be installed in a location and manner so they do not cause erosion or stream bank degradation. Where pumps are located on or within a stream, any impact on the riparian zone caused by the pump installations or their associated access tracks need to be minimised.

Storages: should be constructed to minimise the risk of failure, seepage and deep drainage losses, prevent by-wash erosion, and not cause adverse impacts to natural overland flows. To prevent bank collapse and erosion, batter slopes should be less than 1:3 (vertical:horizontal) generally and less than 1:4 for any part of the embankment located below flood level on a floodplain. Crests should also be wider than either 3 m or the height of the embankment + 1 m, whichever is the greater, to ensure they are stable.

Channels: There is a high risk of seepage when using earthen distribution channels. Seepage should be minimised; it represents not only a waste of precious water but it can also cause salinity, contribute to erosion, and weaken banks. Protection from erosion is also required for channel structures such as bubblers, check structures or inverted syphons.

Application method: can involve simple, low-technology approaches such as flooding, through to more complex technologies such as sprays and drippers. Irrigation can contribute to erosion in paddocks by washing soil along furrows or across rows, or in channels or outlets where velocity is excessive.

The risk of erosion varies between different application methods, soil types and slope (Table 14.5). However, as a general rule, when using flood irrigation, the tail-drain flow velocity should be less than 0.45 metres per second, the furrow cross-fall less than 0.5%, and the drop from bare or cultivated soil at the end of a furrow into the tail drain should be < 25 cm (measured from end of furrow to floor of tail drain).

Table 14.5: General slope thresholds for different crop types and irrigation methods to avoid erosion (Department of Natural Resources and Mines 2005)

Crop	Flood	Spray	Drip
Examples	*(siphons, lay flat and gated pipe)*	*(pivots, hand shift, solid set, lateral moves and travelling guns)*	*(permanent and temporary subsurface drip micro systems)*
Cotton, forage and grain crops	1 in 50 (2%)	1 in 30 (3%)	1 in 50 (2%)
Intensive small crops		1 in 25 (4%)	1 in 25 (4%)
Perennial tree and vine crops		1 in 15 (7%)	1 in 15 (7%)

14.8 Pipelines

Installing pipelines generally involves extensive vegetation clearing as well as excavation, mixing and compaction of soil. In addition, it is also usually necessary as part of the ongoing operation of a pipeline to maintain a strip of land either side of the pipeline, graded and relatively free of vegetation, to allow access to inspect and repair the pipeline as required following construction. Pipelines are generally aligned pragmatically to meet the overwhelming objective of efficiently transporting materials from one location to another with limited consideration to landscape conditions. Whilst some sections may be well aligned to avoid erosion it would be unusual if this were the case for the whole alignment. Special measures to control erosion will normally be required during construction of a pipeline, throughout its operating life, and if/when it is decommissioned, until the site is restored to a natural condition.

The following good soil management principles (Biggs 2010) should generally be applied to minimise erosion in a pipeline corridor:

- If practical, avoid pipeline trenching during high-intensity rainfall periods, when open trenches can concentrate runoff resulting in erosion to adjacent lands.
- Extracted soil materials should be excavated and stockpiled to allow a natural soil profile to be reinstated after construction has been completed. To achieve this it may be necessary to separately strip and preserve topsoil materials and to identify and separate subsoil materials that are chemically or physically different.
- As far as practicable, the time for which excavations are open and extracted material is stockpiled should be minimised.
- Surface soils should be excavated, stockpiled, handled and replaced in ways that do not permanently affect the fertility or productivity of that soil.
- Implement suitable erosion and sediment control measures during the construction phase and until such time as a protective ground cover has re-established on the disturbed areas along the pipeline.
- Provide suitably designed diversion banks or drains to divert overland flow away from excavations, but also to avoid concentration of flow at drainage discharge points.
- Control vehicle and machinery traffic in the pipeline corridor, both during and after construction, to reduce the risk of erosion and compaction. This may require protecting trafficable surfaces with gravelling, watering or sealing.
- Reinstate or replace pre-existing erosion control structures with appropriately designed measures that provide similar or superior protection against erosion.
- Establish protective ground cover on disturbed areas as soon as possible after construction. This may involve sowing cover crops or applying temporary surface mulches where seasonal conditions are not conducive to rapidly re-establishing a permanent soil cover once the excavation has been filled.
- Where subsoils are dispersive, measures to minimise the risk of erosive piping, such as compacting subsoil infill materials and installing trench barriers, should be considered.
- Protect surface and near-surface soil materials that will constitute the root zone of post-construction vegetative cover, from degradation, such as compaction, that might increase the bulk density of that soil or substantially affect its plant available water capacity.

- Do not locate permanent stockpiles of surplus soil materials where they may be incompatible with some post-development land uses (e.g. cropping land or high conservation value land) or where they may represent an erosion hazard by diverting and concentrating runoff. In areas where permanent stockpiles are acceptable (e.g. lower-value grazing land), protect them from soil dispersion and erosion.

14.8.1 Disposing of surplus spoil

Construction of any large-diameter pipeline will result in considerable quantities of surplus soil/substrate materials. The amount of surplus will be determined by factors such as pipe/trench sizes, the expansion ratio of the soil, and the extent to which it is compacted when backfilling excavations. Disposing of surplus material represents a large potential cost and liability. Excess material may be disposed of within the pipeline corridor, or off-site. In all instances though, it is necessary to ensure that the excess material does not cause on-site or off-site problems in either the short- or long-term. Surplus soil may be disposed of by the following three options:

- stockpile or spread and remediate (either on- or off-site)
- dispose to elsewhere e.g. coal mine
- beneficial reuse, e.g. road or other construction purposes.

When disposing of surplus soil off-site the most appropriate option will be determined by factors such as:

- geographic location and transport routes
- general nature of the material (soil versus rock)
- specific nature of the material (soil chemistry, rock type etc.)
- quantity of material
- topography
- local reuse options.

When disposing of surplus fill off-site, particular attention should be given to ensuring that it does not divert and concentrate runoff and cause erosion.

14.9 Further Information

References

Biggs, A. (2010) *Guideline: Land management measures for trenching, pipe laying and backfilling linear infrastructure*, Version 1.0, Department of Environment and Resource Management, Brisbane.

Boulter, S. L., Wilson, B. A., Westrup, J., Anderson, E. R., Turner, E. J. and Scanlan, J. C. (Eds) (2000) *Native vegetation management in Queensland: Background, science and values*, Department of Natural Resources, Brisbane.

Department of Natural Resources and Mines (2005) *Guidelines for land and water management plans: Fitzroy Basin*, The State of Queensland, Rockhampton.

New South Wales Department of Primary Industries (2014) *Primefact 326: Water requirements for sheep and cattle*, dpi.nsw.gov.au/agriculture/emergency/drought/planning/strategies/water-requirements-sheep-cattle (accessed 8 July 2015).

Shellberg, J. and Brooks, A. (2013). *Alluvial gully prevention and rehabilitation options for reducing sediment loads in the Normanby Catchment and northern Australia*, final report for the Australian Government's Caring for our Country—Reef Rescue Initiative, prepared by Australian Rivers Institute, Griffith University, Brisbane.

Staton, J. and O'Sullivan, J. (2006) Stock and waterways: *A manager's guide*, Land & Water Australia, Canberra.

Other information

Information about erosion control on property roads and tracks and on erosion control along fences is provided in the following DNRM fact sheets (searchable at publications.qld.gov.au/dataset/science-notes-soil-and-land-management :

- L239 Erosion control on property roads and tracks – Cross-sections and locations
- L240 Erosion control on property roads and tracks – Managing runoff
- L241 Erosion control on fences and firebreaks.

Information on managing riparian land is available from the following fact sheets:

- Peck, G. (2006) Property planning: Fencing to land type—riparian lands, Fitzroy Basin Association, Rockhampton.
- Department of Environment and Resource Management R33 Managing stock in and around waterways.

Information about erosion control on firebreaks is provided on the Rural Fire Services website ruralfire.qld.gov.au.

Information about irrigation infrastructure is provided in the State of Queensland (1984) *Farm water supplies design manual*, 2nd edition (A. J. Horton and G. A. Jobling, Eds), Queensland Water Resources Commission, Brisbane. In particular, see:

- Volume 1: farm storages
- Volume 2: irrigation systems
- Volume 3: drainage pumps, stock and domestic water supplies.